

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1-25. Cancelled.

26. (Currently Amended) A method of bonding rubber to a metal substrate, the method comprising:

applying a silane solution comprising a substantially hydrolyzed amino-silane and a substantially hydrolyzed sulfur-containing silane to at least a portion of a surface of the metal substrate;

drying the silane solution on the metal substrate to form a coating having a thickness in the range from about 0.1 μm to ~~about~~ less than 1 μm thereon; and

applying an uncured rubber onto the surface of the metal substrate having the coating thereon and curing the rubber to bond the rubber to the coated metal substrate.

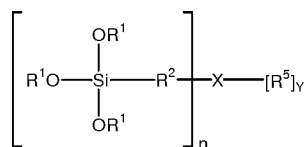
27. (Original) The method of claim 26 further comprising, prior to applying the solution:

mixing an amino-silane and a sulfur-containing silane separately with an aqueous-based medium to substantially hydrolyze the amino-silane and the sulfur-containing silane; and

mixing the hydrolyzed amino-silane and the hydrolyzed sulfur-containing silane together to form the solution to be applied to the metal substrate.

28. (Original) The method of claim 27 wherein the aqueous-based medium comprises water and alcohol.

29. (Original) The method of claim 27 wherein the amino-silane is a compound of the general formula I

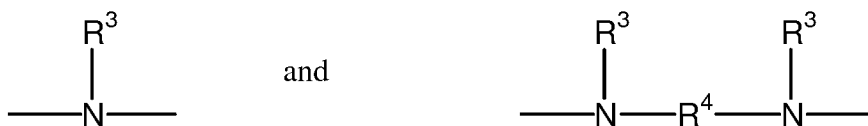


wherein:

each R^1 , independently, is selected from the group consisting of substituted or unsubstituted, straight, branched or cyclic $\text{C}_1\text{-C}_{20}$ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted $\text{C}_3\text{-C}_{20}$ aryl and alkylaryl groups;

each R^2 , independently, is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic $\text{C}_1\text{-C}_{20}$ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted $\text{C}_3\text{-C}_{20}$ aryl and alkylaryl groups;

X is selected from the group consisting of



wherein each R^3 , independently, is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic $\text{C}_1\text{-C}_{20}$ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted $\text{C}_3\text{-C}_{20}$ aryl and alkylaryl groups; and

R^4 is selected from the group consisting of hydrogen, substituted or unsubstituted,

straight, branched or cyclic C₁-C₂₀ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups;

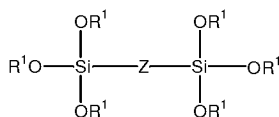
R⁵ is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic C₁-C₂₀ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups;

n is an integer selected from the group consisting of 1 and 2; and

y is (2-n).

30. (Original) The method of claim 27 wherein the amino silane is selected from the group consisting of bis(trimethoxysilylpropyl)ethylene diamine, bis(trimethoxysilylpropyl) amine, N-methyl-aminopropyltriethoxysilane, and combinations thereof.

31. (Original) The method of claim 27 wherein the sulfur-containing silane is a compound of the general formula II



wherein:

each R¹, independently, is selected from the group consisting of substituted or unsubstituted, straight, branched or cyclic C₁-C₂₀ alkyl, alkenyl, alkynyl, and acetyl groups and substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups;

Z is -Q-S_x-Q, wherein each Q, independently, is an aliphatic or aromatic group; and

x is an integer from 2 - 10.

32. (Original) The method of claim 27 wherein the sulfur-containing silane is selected from the group consisting of bis(trimethoxysilylpropyl) disulfide, bis(trimethoxysilylpropyl) tetrasulfide, and a combination thereof.

33. (Original) The method of claim 26 wherein the solution comprises a ratio of the hydrolyzed amino-silane to the hydrolyzed sulfur-containing silane in a range from about 1:4 to about 4:1 by volume.

34. (Original) The method of claim 26 wherein the solution comprises a ratio of the hydrolyzed amino-silane to the hydrolyzed sulfur-containing silane of about 1:1 by volume.

35. (Original) The method of claim 26 wherein applying the solution to the metal substrate comprises dipping the metal substrate in the solution.

36. (Original) The method of claim 26 wherein the solution applied to the metal substrate further comprises a nanosize particulate material.

37. (Original) The method of claim 36 wherein the nanosize particulate material is selected from the group consisting of silica, zinc oxide, and combinations thereof.

38. (Original) The method of claim 36 wherein the nanosize particulate material has an average particle size of about 0.1 μm or less.

39. (Original) The method of claim 36 wherein the nanosize particulate material is silica and in a concentration range from about 10 ppm to about 1% by weight of the solution.

40. (Original) The method of claim 36 wherein the nanosize particulate material is silica and in a concentration range from about 50 ppm to about 1000 ppm of the solution.

41. (Original) The method of claim 26 wherein drying comprises heating the silane solution on the metal substrate to a temperature of at least about 60°C.

42. (Original) The method of claim 26 wherein the coating formed has a thickness in the range from about 0.2 μm to about 0.6 μm .

43. (Previously Presented) The method of claim 26 wherein curing comprises applying heat and pressure to the rubber and coated metal substrate to form a bond therebetween.

44-45. Cancelled.

46. (Currently Amended) A method of bonding rubber to a metal substrate, the method comprising:

mixing an amino-silane and a sulfur-containing silane separately with an aqueous-based medium to substantially hydrolyze the amino-silane and the sulfur-containing silane;

mixing the hydrolyzed amino-silane, the hydrolyzed sulfur-containing silane, and a nanosize particulate material having an average particle size of about 0.1 μm or less, together to form a silane solution comprising a ratio of the hydrolyzed amino-silane to the hydrolyzed sulfur-containing silane in a range from about 1:4 to about 4:1 by volume,

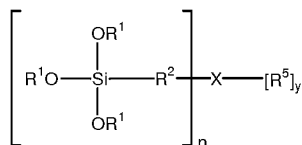
applying the solution to at least a portion of a surface of the metal substrate in an amount sufficient to form a coating to a thickness in the range from about 0.1 μm to ~~about~~ less than 1 μm ; and

drying the solution on the metal substrate to form the coating thereon;

applying an uncured rubber onto the surface of the metal substrate having the solution applied thereon; and

curing the rubber with heat and pressure to bond the rubber to the metal substrate.

47. (Original) The method of claim 46 wherein the amino-silane is a compound of the general formula I



wherein:

each R^1 , independently, is selected from the group consisting of substituted or unsubstituted, straight, branched or cyclic $\text{C}_1\text{-C}_{20}$ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted $\text{C}_3\text{-C}_{20}$ aryl and alkylaryl groups;

each R^2 , independently, is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic $\text{C}_1\text{-C}_{20}$ alkyl, alkenyl, and alkynyl groups and

substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups;

X is selected from the group consisting of



wherein each R³, independently, is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic C₁-C₂₀ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups; and

R⁴ is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic C₁-C₂₀ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups;

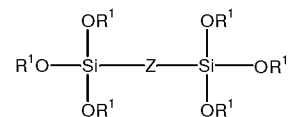
R⁵ is selected from the group consisting of hydrogen, substituted or unsubstituted, straight, branched or cyclic C₁-C₂₀ alkyl, alkenyl, and alkynyl groups and substituted or unsubstituted C₃-C₂₀ aryl and alkylaryl groups;

n is an integer selected from the group consisting of 1 and 2; and

y is (2-n).

48. (Original) The method of claim 46 wherein the amino silane is selected from the group consisting of bis(trimethoxysilylpropyl)ethylene diamine, bis(trimethoxysilylpropyl) amine, N-methyl-aminopropyltriethoxysilane, and combinations thereof.

49. (Original) The method of claim 46 wherein the sulfur-containing silane is a compound of the general formula II



wherein:

each R^1 , independently, is selected from the group consisting of substituted or unsubstituted, straight, branched or cyclic $\text{C}_1\text{-C}_{20}$ alkyl, alkenyl, alkynyl, and acetyl groups and substituted or unsubstituted $\text{C}_3\text{-C}_{20}$ aryl and alkylaryl groups;

Z is $-\text{Q-S}_x\text{-Q}$, wherein each Q, independently, is an aliphatic or aromatic group; and

x is an integer from 2 - 10.

50. (Original) The method of claim 46 wherein the sulfur-containing silane is selected from the group consisting of bis(trimethoxysilylpropyl) disulfide, bis(trimethoxysilylpropyl) tetrasulfide, and a combination thereof.

51. (Original) The method of claim 46 wherein the solution applied to the metal comprises a ratio of the hydrolyzed amino-silane to the hydrolyzed sulfur-containing silane of about 1:1 by volume.

52. (Original) The method of claim 46 wherein the nanosize particulate material is selected from the group consisting of silica, zinc oxide, and combinations thereof.

53. (Original) The method of claim 46 wherein the nanosize particulate material is silica and in a concentration range from about 10 ppm to about 1% by weight of the solution.

54. (Original) The method of claim 46 wherein the nanosize particulate material is silica and in a concentration range from about 50 ppm to about 1000 ppm of the solution.

55. (Original) The method of claim 46 wherein the coating formed has a thickness in the range from about 0.2 μm to about 0.6 μm .

56-96. Cancelled

97. (Previously Presented) The method of claim 26 wherein the rubber is selected from the group consisting of natural rubber, synthetic rubber, and combinations thereof.

98. (Previously Presented) The method of claim 26 wherein the rubber is selected from the group consisting of sulfur-cured rubber, peroxide-cured rubber, and combinations thereof.

99. (Previously Presented) The method of claim 46 wherein the rubber is selected from the group consisting of natural rubber, synthetic rubber, and combinations thereof.

100. (Previously Presented) The method of claim 46 wherein the rubber is selected from the group consisting of sulfur-cured rubber, peroxide-cured rubber, and combinations thereof.